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CHAPTER 3

STABILIZATION WITH PORTLAND CEMENT

3-1. Stabilization approaches. Portland cement can be used either to modify and improve the quality of the soil or to transform the soil into a cemented mass, which significantly increases its strength and durability. The amount of cement additive will depend upon whether the soil is to be modified or stabilized.

3-2. Cement content for modification of soils.

a. Modification of quality. The amount of cement required to improve the quality of the soil through modification is determined by the trial-and-error approach. If it is desired to reduce the PI of the soil, successive samples of soil-cement mixtures must be prepared at different treatment levels and the PI of each mixture determined. The Referee Test of ASTM D 423 and ASTM D 424 procedures will be used to determine the PI of the soil-cement mixture. The minimum cement content that yields the desired PI is selected, but since it was determined based upon the minus 40 fraction of the material, this value must be adjusted to find the design cement content based upon total sample weight expressed as the following equation:

$$A = 100Bc$$

where:

A = design cement content, percent total weight of soil
B = percent passing No. 40 sieve size, expressed as a decimal
c = percent cement required to obtain the desired PI of minus 40 material, expressed as a decimal.

b. Modification of gradation. If the objective of modification is to improve the gradation of granular soil through the addition of fines, the particle-size analysis, using the ASTM D 422 procedure, should be conducted on samples at various treatment levels to determine the minimum acceptable cement content. The determination of cement content to reduce the swell potential of fine-grained plastic soils can be accomplished by molding several samples at various cement contents and soaking the specimens along with untreated specimens for 4 days. The lowest cement content that eliminates the swell potential or reduces the swell characteristics to the minimum becomes the design cement content. Procedures for measuring swell characteristics of soils are found in MIL-STD-621, Method 101. The cement content determined to accomplish soil modification should be checked to see whether it provides an unconfined compressive strength great enough to qualify for a reduced thickness design in accordance with criteria established for soil stabilization.

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c. Modification for frost areas. Cement-modified soil also may be used in frost areas, but in addition to the procedures for mixture design described in 3-2.a. and 3-2.b. above, cured specimens should be subjected to the freeze-thaw cycles prescribed by ASTM D 560 (but omitting wire-brushing) or other applicable freeze-thaw procedures, followed by frost-susceptibility determinations in standard laboratory freezing tests. For cement-modified soil used in the base course, the frost susceptibility, determined after freeze-thaw cycling, should meet the requirements set forth for the base course. If cement-modified soil is used as the subgrade, its frost susceptibility, determined after freeze-thaw cycling, should be used as the basis of the pavement thickness design if the reduced subgrade strength design method is applied (EM 1110-3-138). For mobilization, the use of ASTM D 560 may be altered to 6 cycles of 6 hours of freeze/wet - 6 hour thaw/dry. Percentages of stabilizer selected for use may be based on local performance history in lieu of these tests.

3-3. Cement content for cement-stabilized soil. The following procedure is recommended for determining the design cement content for cement-stabilized soils.

a. Step 1. Determine the classification and gradation of the untreated soil following procedures in MIL-STD-619 and ASTM D 422, respectively. The soil must meet the gradation requirements shown in table 3-1 before it can be used in a reduced thickness design.

Table 3-1. Gradation Requirements

<u>Type</u> <u>Course</u>	<u>Sieve</u> <u>Size</u>	<u>Percent</u> <u>Passing</u>
Base	2-inch	100
	1-1/2-inch	70-100
	1-inch	45-100
	3/4-inch	--
	1/2-inch	30-90
	No. 4	20-70
	No. 10	15-60
	No. 30	--
	No. 40	5-40
	No. 200	0-20
Subbase	3-inch	100
	No. 4	--
	No. 10	--
	No. 100	--
	No. 200	0-25

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b. Step 2. Select an estimated cement content from table 3-2 using the soil classification.

Table 3-2. Estimated Cement Requirements for Various Soil Types

<u>Soil Classification^a</u>	<u>Initial Estimated Cement Requirement Percent Dry Weight</u>
GW-SW	5
GP, SW-SM, SW-SC, SW-GM, SW-GC	6
GM, SM, GC, SC, SP-SM, SP-SC, GP-GM GP-GC, SM-SC, GM-GC	7
SP, CL, ML, ML-CL	10
MH, OH	11
CH	10

^a Soil classification corresponds to MIL-STD-619.

c. Step 3. Using the estimated cement content, determine the moisture-density relations of the soil-cement mixture. The procedure contained in ASTM D 558 will be used to prepare the soil-cement mixture and to make the necessary calculations; however, the apparatus and procedures outlined in MIL-STD-621, Method 100, Compaction Effort Designation CE-55 will be used to compact the soil-cement mixture.

d. Step 4. Using the untreated soil gradation characteristics, cement content, and maximum dry density determined in Steps 1, 2, and 3, respectively, verify the estimated cement content using table 3-3 or table 3-4 and figure 3-1 depending upon soil classification. If the estimated cement content from Step 2 varies by more than plus or minus 2 percent from the value in table 3-3 or table 3-4, conduct additional moisture-density tests, varying the cement content, until the value from table 3-3 or table 3-4 is within plus or minus 2 percent of that used for the moisture-density test. The moisture-density test will be performed as outlined in Step 3.

e. Step 5. Prepare samples of the soil-cement mixture for unconfined compression and durability tests at the dry density and at the cement content determined in Step 4 and at cement contents 2

Table 3-3. Average Cement Requirements for Granular and Sandy Soils

Material Retained on No. 4 Sieve percent	Material Smaller Than 0.05 mm percent	Cement Content, Percent by Weight Maximum Dry Density, pcf (Treated Material)					
		116-120	121-126	127-131	132-137	138-142	143 or more
0-14	0-19	10	9	8	7	6	5
	20-39	9	8	7	7	5	5
	40-50	11	10	9	8	6	5
15-29	0-19	10	9	8	6	5	5
	20-39	9	8	7	6	6	5
	40-50	12	10	9	8	7	6
30-45	0-19	10	8	7	6	5	5
	20-39	11	9	8	7	6	5
	40-50	12	11	10	9	8	6

Note: Base course goes to 70 percent retained on the No. 4 sieve.

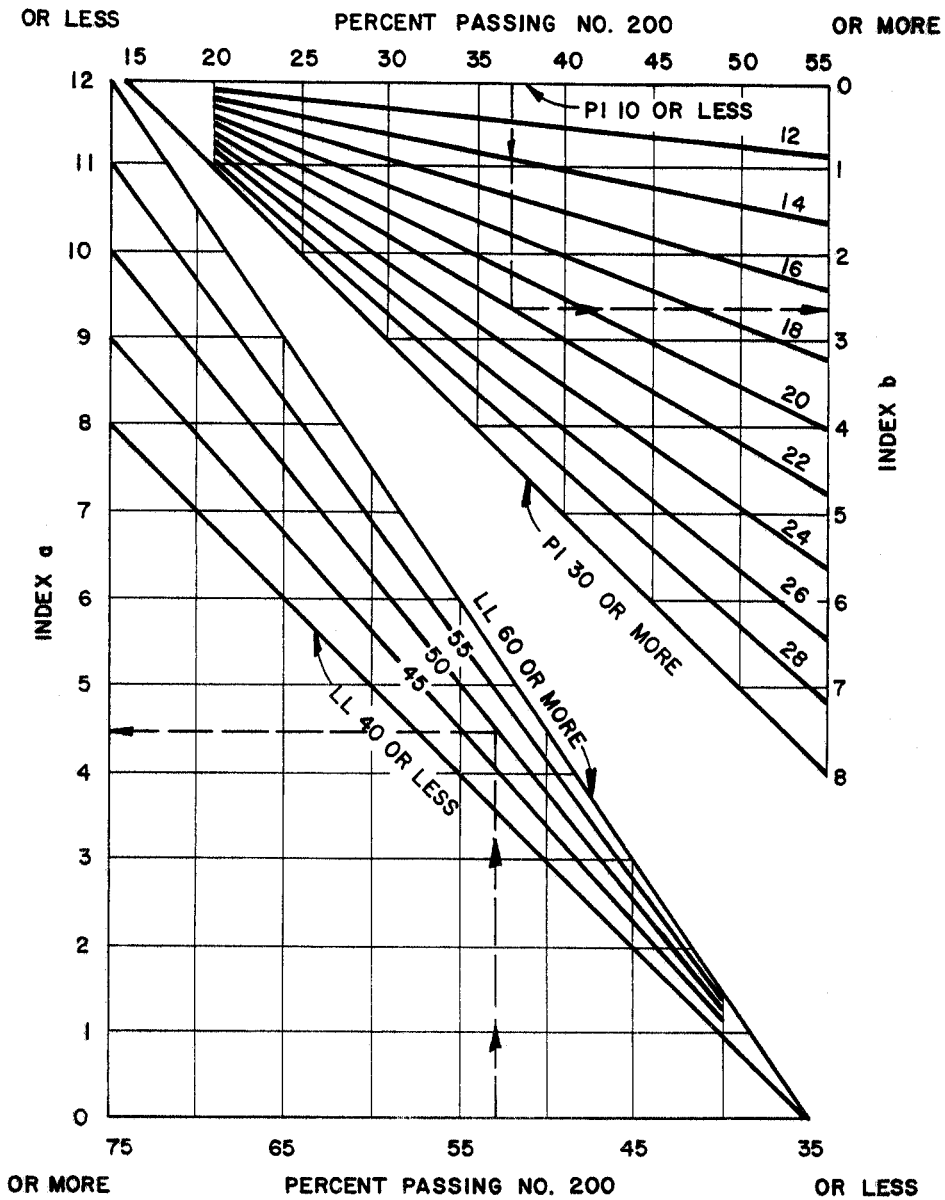
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Table 3-4. Average Cement Requirements for Silty and Clayey Soils

Group Index ^a	Material Between 0.05 and 0.005 mm percent	Cement Content, Percent by Weight Maximum Dry Density, pcf (Treated Material)						
		99-104	105-109	110-115	116-120	121-126	127-131	132 or more
0-3	0-19	12	11	10	8	8	7	7
	20-39	12	11	10	9	8	8	7
	40-59	13	12	11	9	9	8	8
	60 or more	--	--	--	--	--	--	--
3-7	0-19	13	12	11	9	8	7	7
	20-39	13	12	11	10	9	8	8
	40-59	14	13	12	10	10	9	8
	60 or more	15	14	12	11	10	9	9
5-9	0-19	14	13	11	10	9	8	8
	20-39	15	14	11	10	9	9	9
	40-59	16	14	12	11	10	10	9
	60 or more	17	15	13	11	10	10	10
11-15	0-19	15	14	13	12	11	9	9
	20-39	16	15	13	12	11	10	10
	40-59	17	16	14	12	12	11	10
	60 or more	18	16	14	13	12	11	11
15-20	0-19	17	16	14	13	12	11	10
	20-39	18	17	15	14	13	11	11
	40-59	19	18	15	14	14	12	12
	60 or more	20	19	16	15	14	13	12

^aTaken from figure 3-1

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NOTE: Group Index = Index a + Index b.

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FIGURE 3-1. CHARTS FOR CALCULATING GROUP INDEX VALUES

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percent above and 2 percent below that determined in Step 4. The samples should be prepared in accordance with ASTM D 1632 except that when more than 35 percent of the material is retained on the No. 4 sieve, a 4-inch-diameter by 8-inch-high mold should be used to prepare the specimens. Cure the specimens for 7 days in a humid room before testing. Test three specimens using the unconfined compression test in accordance with ASTM D 1633, and subject three specimens to durability tests, either wet-dry (ASTM D 559) tests for pavements located in nonfrost areas or freeze-thaw (ASTM D 560) tests for pavements located in frost areas (EM 1110-3-138). For mobilization, the use of ASTM D 560 may be altered to 6 cycles of 6 hours of freeze/wet - 6 hour thaw/dry. Percentages of stabilizer selected for use may be based on local performance history in lieu of these tests.

f. Step 6. Compare the results of the unconfined compressive strength and durability tests with the requirements shown in tables 2-1 and 3-5. The lowest cement content, which meets the required unconfined compressive strength requirement and demonstrates the required durability, is the design cement content. If the mixture should meet the durability requirements but not the strength requirements, the mixture is considered to be a modified soil.

Table 3-5. Durability Requirements

Type of Soil Stabilized ^a	Maximum Allowable Weight Loss After 12 Wet-Dry or 6 Freeze-Thaw Cycles	
	<u>Percent of Initial Specimen Weight</u>	
Granular, PI less than 10	11	
Granular, PI greater than 10	8	
Silt	8	
Clays	6	

^aRefer to MIL-STD-619 and MIL-STD-621.